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**Preliminary Report of Noise Impacts at Cincinnati Music Hall Resulting From The**

# FC Cincinnati Stadium Environmental Noise Model

**Prepared for:**
CINCINNATI ARTS ASSOCIATION
Cincinnati, Ohio

CINCINNATI SYMPHONY ORCHESTRA
Cincinnati, Ohio

CINCINNATI OPERA
Cincinnati, Ohio

CINCINNATI BALLET
Cincinnati, Ohio

**Akustiks Project #18-0780**
**31 January 2019**

93 North Main Street | Suite 2 | Norwalk, CT 06854 203.299.1904 akustiks.com

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31 January 2019

Mr. Stephen A. Loftin
Cincinnati Arts Association
1241 Elm Street
Cincinnati Ohio 45202

Re: FC Cincinnati Stadium Noise Impact Study
AKS Project #18-0780

Dear Steve,

Enclosed is the first draft of our report documenting the results of an environmental noise model that we have prepared to assess the impact of the planned new FC Cincinnati Stadium on Music Hall. This will allow the Cincinnati Arts Association and the resident companies at Music Hall to understand if and how their operations in Music Hall would be affected by events at the new stadium.

This preliminary report includes an executive summary, an outline of the study methodology, and a detailed discussion of the results. The final report will include these elements as well as a discussion of potential mitigation strategies for the negative impacts discovered in the study.

I hope that you find the enclosed to be both informative and interesting. Please call me if you have any questions or need elaboration on any aspect of the report.

Sincerely,

Paul H. Scarbrough
Principal

## FC Cincinnati Stadium Noise Impact Study

Akustiks, LLC ("Akustiks") was engaged by the Cincinnati Arts Association to prepare an environmental noise model of the neighbourhood around the planned FC Cincinnati Stadium in the West End portion of downtown Cincinnati. The fundamental purpose of this model was to assess whether stadium operations would have a negative impact on rehearsals, performances and other activities in Music Hall.

In summary, the scope of work included the following elements:

1.01 Gather information about the existing ambient noise environment in the area of Music Hall and the new stadium.

1.02 Gather information about the physical environment, including topography, existing structures, the designs for the new stadium and its key features.

1.03 Construct a computer environmental noise model of the stadium and its environs.

1.04 Project the impact of stadium operations on the community with a specific emphasis on Cincinnati Music Hall. This will include normal operations of the FC Cincinnati Stadium as well as potential use of the stadium for high-level amplified contemporary music concerts.

1.05 To the degree that negative impacts on Music Hall are identified by the study, explore whether there are reasonable mitigation measures that could be implemented as part of the stadium design or within Music Hall.

This report includes the following sections:

1.01 An executive summary offering a high-level overview of the key study findings.

1.02 An outline of the methodology employed to complete the study.

1.03 A glossary of acoustical terminology used in this report.

1.04 A detailed discussion of the results from the environmental noise model.

1.05 An exploration of potential mitigation measures that could be implemented as part of the stadium design or within Music Hall (under development).

## 1.0 Executive Summary

1.01 Akustiks prepared an environmental noise model for the planned FC Cincinnati Stadium and its immediate environs, including an area sufficient to encompass the full perimeter of Cincinnati Music Hall. This model was prepared using SoundPlan, a comprehensive noise modeling software package that allows one to create a three-dimensional representation of the study area including all of the structures of interest, both existing and proposed. We then simulated three conditions:

a. A typical soccer match with a full stadium of 26,000 fans

b. A high-level amplified contemporary music concert with the stage positioned at the north end of the field facing to the south.

c. A high-level amplified contemporary music concert with the stage positioned at the south end of the field facing to the north.

1.02 Model results revealed the following impacts on Springer Hall:

a. Crowd noise from soccer matches will be readily audible in Springer Auditorium. The model predicts that at its peak (fans responding to a home team goal, for example), crowd noise will exceed the background noise in Music Hall by between as much as 12 dB at some frequencies. This noise would be readily audible by the audience and the performers and would interfere with the subtle moments of performances by the resident companies.

b. Both the audio and crowd noise from high-level amplified contemporary music concerts would be audible in Springer Auditorium. Unlike the crowd noise impacts from soccer matches, which are focused on mid and low frequencies (i.e., the peak of the human vocal range), the impacts from amplified concerts in the stadium would be evident across much of the frequency range. The impacts are greatest when the stage is positioned at the north end of the field facing toward the south (i.e., toward Music Hall) In this scenario, at very low frequencies (the octave bands at 63 Hz. and 125 Hz.), the intrusion would be between 11 and 15 dB higher than the background noise in Springer. This would be readily audible by the audience and the performers and would prove disruptive to both rehearsals and performances.

1.03 Model results revealed the following impacts on the May Festival Chorus Rehearsal Room:

a. It appears that crowd noise from soccer matches would not be audible in the Rehearsal Room. The Rehearsal Room features more robust sound isolation to the exterior and this reduces the amount of exterior sound that penetrates to the interior. The space also has a higher background noise level (from HVAC systems) that serves to mask some intrusive noise and render it harder to hear. The intrusion from crowd noise appears to be at least 10 dB below the background noise in the Rehearsal Room, which generally renders an intrusive noise inaudible.

b. With high-level amplified contemporary music concerts, impacts in the Rehearsal Room are evident in the low frequency octave bands at 63 Hz. and 125 Hz.. This means that Rehearsal Room occupants may be aware of the beat associated with concert music in the stadium. This is likely to prove disruptive to rehearsals.

1.04 Model results revealed the following impacts on the Ballroom:

a. Results pending

b. Results pending

1.05 It is clear that mitigation will be required to address the impacts revealed in the FC Cincinnati Stadium noise impact study.

a. To be developed

b. To be developed

## 2.0 Study Methodology

2.01 To prepare this assessment, Akustiks prepared a model of the site using SoundPlan, a sophisticated noise modeling and mapping software package. The model is a three-dimensional digital representation of the site including the entire built environment, both existing and proposed. Layered onto this representation are the various noise sources at the site: traffic and, in this case, the amplified sound associated with FC Cincinnati Stadium events. The model then projects the noise levels throughout the site, allowing us to understand how events in the stadium will impact the environs.

2.02 The following source documents were used in the preparation of the SoundPlan model:

a. Site plans and a three-dimensional architectural model of the proposed FC Cincinnati Stadium supplied by the FC Cincinnati design team. The area modeled extends from above West Liberty Street on the north, to the region of Jones Street on the west, the region of Grant Street to the south and midway across Washington Park on the east.

b. Information on the key stadium construction materials supplied by the FC Cincinnati design team. We used manufacturer transmission loss data for materials when such data was available. When such data was not available, we calculated the transmission loss performance of the materials using Insul, an industry standard software package for modeling the performance of materials and construction assemblies.

c. Information on existing building locations and profiles throughout the neighborhood from published online sources such as Google Earth and Google Maps.

d. Data on the frequency spectrum of the human voice at a high level of effort (shouting) from a published source by Leo L. Beranek.

e. In-house measurement data on typical third-octave band sound pressure levels at the house mix location for large scale contemporary music concerts. Spectra from a number of events were examined and a normalized or idealized spectrum developed for use in the model.

2.03 Once the model was complete, we modeled three different scenarios:

a. Scenario 1: A typical soccer match. For this scenario, we assumed that the stadium was full (26,000 fans), and that 75% of the fans were cheering at a high level in response to a hometown team goal or other match event. Based upon this input, the

model generated levels of approximately 105 dBA on the field, which is consistent with data measured by the FC Cincinnati AV consultant at other Major League Soccer facilities. Graph #1 in the appendix presents the spectrum for this sound source.

b. Scenario 2: A typical highly amplified contemporary music concert. For this scenario, we placed the stage at the north end of the field and oriented it to face the south. This source produces approximately 108 dBA or 120 dBC at the house mix location, which is 150-feet from the loudspeaker array at the stage. Graph #2 in the appendix presents the spectrum for this sound source.

c. Scenario 3: A typical highly amplified contemporary music concert. For this scenario, we placed the stage at the south end of the field and oriented it to face the north. The same spectrum previous described above was used for this scenario.

2.04 For each scenario, we selected appropriate receiver positions on Music Hall and projected the third octave band sound pressure levels at each receiver position.

2.05 We then projected the intrusive noise impact on the interior of selected spaces within Music Hall by subtracting the amount of noise reduction that we observed at three subject areas in Music Hall, namely Springer Auditorium, the May Festival Chorus Rehearsal Room and the Ballroom. The noise reduction values were derived by operating a high-level broad band noise source (shotgun blast) on the roof and simultaneously measuring the noise levels at the roof and inside each subject space.

2.06 The resulting calculated levels were then graphed against NC curves and the measured background noise in each space to assess whether the resultant levels of intrusion were likely to be audible and/or disruptive.

## 3.0 Definitions

In reading this report, it is important to understand certain terminology and how it is being used in this context:

3.01 Ambient Noise
Noise that is more or less continuous in an urban environment. In most urban environments this comprises noise from vehicular traffic, external building mechanical equipment, and other continuous sound sources. While ambient noise levels in a particular area may rise or fall over time, they almost never disappear entirely. Ambient noise is always present, but it is not necessarily steady state.

3.02 Intrusive Noise
This refers to noise associated with non-continuous sound sources. Examples include construction activities, children in a playground, crowd noise at a sporting event, background music in an open-air bar or restaurant, and live sound associated with a performance.

3.03 dBA
Decibels (dB) measured using the A-weighting network. This is a convenient single number reference of the sound pressure level associated with a particular sound source. The A-weighting network aggregates sound levels across the full spectrum of human hearing (from low or bass frequencies to high or treble frequencies). The A-weighting network takes into consideration that at low to moderate sound levels (typically 55 db and below) the human ear is more sensitive to mid-frequency and high frequency sound and less sensitive to low frequency sound.

3.04 dBC
Decibels (dB) measured using the C-weighting network. This is a convenient single number reference of the sound pressure level for higher-level sound sources. Like the A-weighting network, the C-weighting network aggregates sound levels across the full spectrum of human hearing (from low to high frequencies). The C-weighting network is intended for measuring high sound levels (typically 85 dB and above) where the sensitivity of the human ear is more uniform across the frequency spectrum.

3.05 Weighting Network
A schedule of values that either emphasize or de-emphasize the measured sound level in a particular range of frequencies before that level is summed with measurements in other frequency ranges. Weighting networks are used to sum sound levels so that the single number result more closely aligns with human perception of different sound levels. The table below gives these values for the A and C weighting networks defined above. A negative value is subtracted before that level is summed with other measured values. A positive value is added to the measured level before summation.

| Weighting Network | Octave Band Center Frequencies (Hz.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| A (dBA) | -26 | -16 | -9 | -3 | 0 | +1 | +1 | -1 |
| C (dBC) | -1 | 0 | 0 | 0 | 0 | 0 | -1 | -3 |

3.06 Dynamic Range
In music and/or speech (especially in a performance setting), the variation in sound pressure level between the softest and loudest parts of the performance or recording.

3.07 Noise Criteria
Background noise is the term acousticians use to refer to the continuous, low level of sound that is present in almost any interior environment. When analyzing or specifying background noise levels it is essential to employ a method of rating noise that compensates for the fact that the human ear is more sensitive to mid-frequency and high frequency sound than it is to low frequency sound. The Noise Criteria methodology accounts for this imbalance in the human hearing mechanism. Noise Criteria (NC) curves aggregate decibel measurements across the full frequency range of human hearing and then correlate these with subjective impressions of the overall level of background noise in a space. Each curve has a different NC rating number and represents a different noise level as perceived by the human ear. A higher rating connotes a higher perceived level of noise. Through experience and testing acousticians have determined the preferred noise criteria for different activities.

3.08 Transmission Loss
The reduction in sound level, in decibels, as sound transmits across any sort of barrier. The barrier can be a single material or a complex assembly comprising multiple materials. High sound transmission loss means that little sound is transmitted across the material or assembly. Low sound transmission loss means that a large amount of the sound is transmitted across the material or assembly.

## 4.0 Detailed Discussion of the Results: Springer Auditorium

4.01 The results for Springer Auditorium are sobering, as they revealed that even crowd noise by itself can be loud enough to cause intrusion in the house and on stage. This is primarily the result of the comparatively lightweight construction of the roof and the presence of many openings in the plaster ceiling of the auditorium for front of house lighting positions, canopy rigging and the old chandelier exhaust.

4.02 The other factor influencing the results in Springer Auditorium is the exceptionally quiet background noise level in the house. A key priority of the recent renovation project was to reduce excessive noise from the existing HVAC systems serving the house. This effort was successful and the observed background noise levels in Springer Auditorium are now below NC-15 and approach NC-10, world class by almost any standard.

4.03 The results graphs in the appendix illustrate the intrusion created under each scenario. In each graph, frequency is presented along the horizontal axis in octave bands from low or bass frequencies on the left side of the graph to high or treble frequencies on the right. Sound pressure level in decibels (dB) is presented on the vertical axis. The black curve at the bottom of the graph is identified as the Threshold of Hearing, the theoretical lowest level of sound that humans can hear. The light grey curves are the NC curves the were previously defined. The bright green line is the background noise in the subject space. The bright red line is the projected level of the scenario inside the subject space.

4.04 Graph #3 illustrates the intrusion in Springer Auditorium under Scenario 1.

4.05 Graph #4 illustrates the intrusion in Springer Auditorium under Scenario 2.

4.06 Graph #5 illustrates the intrusion in Springer Auditorium under Scenario 3.

## 5.0 Detailed Discussion of the Results: May Festival Chorus Rehearsal Room

5.01 The results for the May Festival Chorus Rehearsal Room do not exhibit as dramatic an intrusion as that observed in Springer Auditorium. It seems likely that crowd noise at soccer games may not be audible.

5.02 The other factor influencing the results in the Rehearsal Room is the comparatively high background noise level. The noise levels in the Rehearsal Room fall between NC-25 and 30, which helps mask or cover the intrusive noise from the exterior.

5.03 Graph #6 illustrates the intrusion in the Chorus Rehearsal Room under Scenario 1.

5.04 Graph #7 illustrates the intrusion in the Chorus Rehearsal Room under Scenario 2.

5.05 Graph #8 illustrates the intrusion in the Chorus Rehearsal Room under Scenario 3.

## 6.0 Detailed Discussion of the Results: Ballroom

6.01 Results pending

6.02 Results pending

6.03 Graph #9 illustrates the intrusion in the Ballroom under Scenario 1.

6.04 Graph #10 illustrates the intrusion in the Ballroom under Scenario 2.

6.05 Graph #11 illustrates the intrusion in the Ballroom under Scenario 3.

## 7.0 Observations on Noise Propagation from the Stadium

7.01 We examined how sound propagates from the stadium in more detail to lay the groundwork for developing mitigation measures. The key findings are as follows:

a. Although the roof provides some containment of the sound, the opening at the center is large enough to allow a significant amount of sound energy, particularly at low frequencies to escape into the neighborhood.

b. There appear to be significant openings between the underside of the roof and the edges of the seating bowl. These allow a considerable amount of sound to propagate into the neighborhood.

c. The elements around the exterior of the stadium, dubbed “ribbons” by the FC Cincinnati stadium design team are not continuous and constructed of very lightweight materials. They are essentially ineffective as barriers to noise propagation.

7.02 Graphs #12 through #15 offer a graphical illustration of how sound propagates from the interior of the stadium to the exterior. These are sectional maps taken through the stadium and they show sound levels in color per the legend at the right side of the page. The section cut through the stadium is taken on a diagonal from the northwest corner of the stadium through the southeast corner (see the key plan on the upper right). The cut line continues to an intersection with Music Hall (the large grey series of blocks on the right side of the graphics).

7.03 Graph #12 shows the propagation of sound due to crowd noise. Note how the roof provides some containment of sound but does not control sound emanating through the large opening at the center. Observe how sound also escapes at the top of the seating bowl.

7.04 The next graph down (#13) shows the impact of the in-house PA system. This is not the actual design for the house PA, as this has not yet been advanced by the design team, but is our best approximation of what such a system would comprise in terms of speaker locations and types. Note how the output of this system is well focused on the seating area and thus minimizes spill outside the stadium. The maximum levels produced by this system at the seating are approximately 90 dBA, which is in line with guidance offered by the FC Cincinnati AV consultant for similar MLS facilities.

7.05 Graph #14 shows the impact of a highly amplified music concert with the stage at the north end of the field facing toward Music Hall. Note how sound diffracts or wraps around the edge of the roof and how it passes through the openings at the top of each section of seating.

7.06 Graph #15 shows the impact of a highly amplified music concert with the stage at the south end of the field facing toward the Cincinnati Ballet Building.

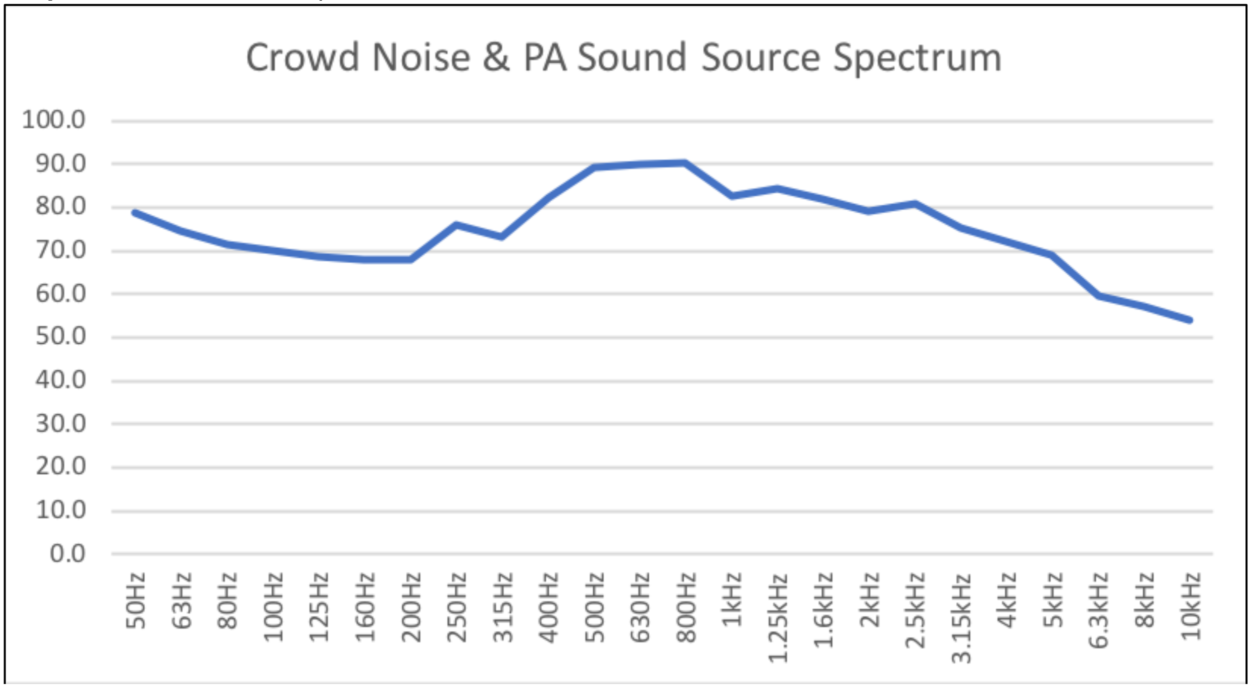
## 8.0 Mitigation Strategies

8.01 Under development

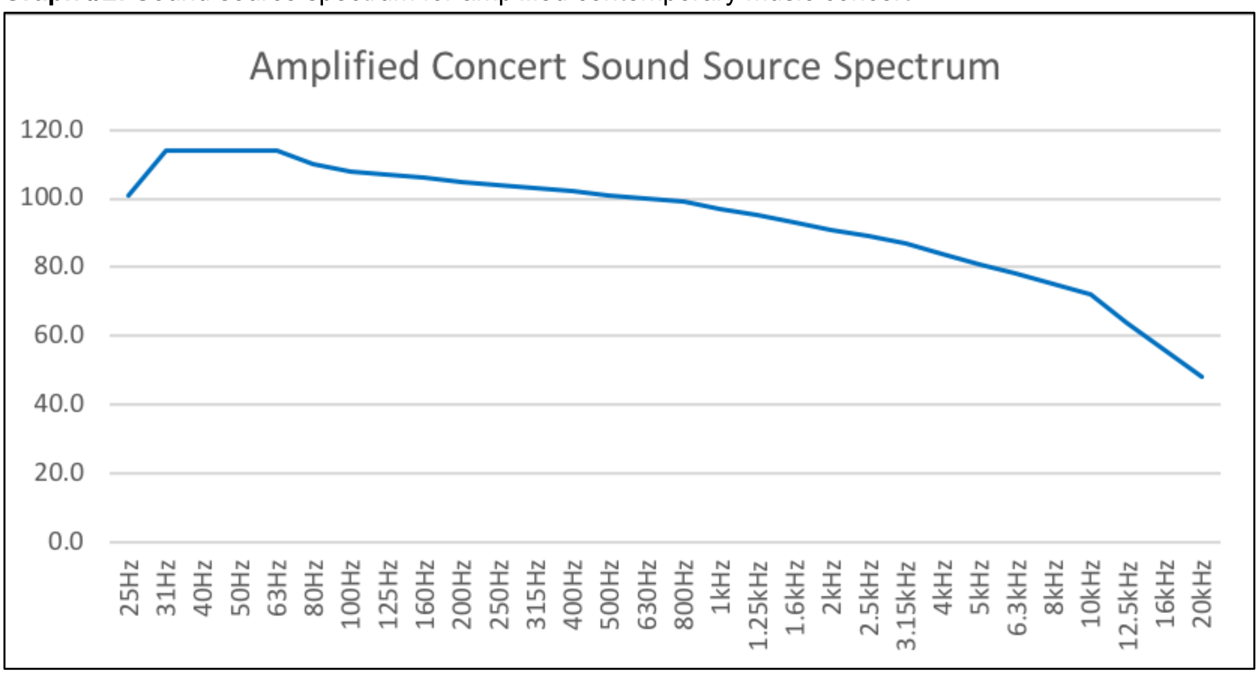
## 9.0 Conclusions

9.01 Under development

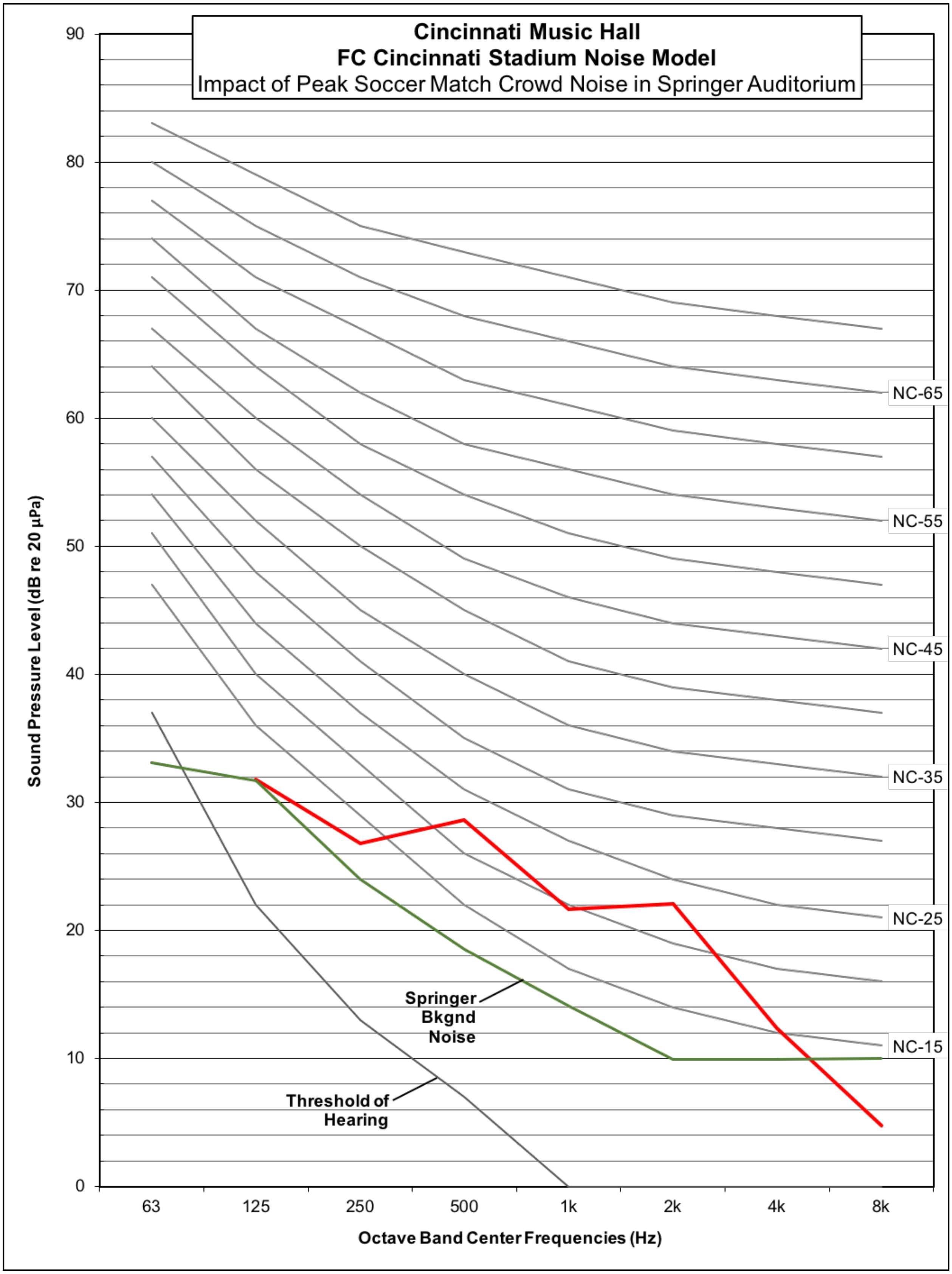
**Graph #1:** Sound source spectrum for crowd noise and stadium PA



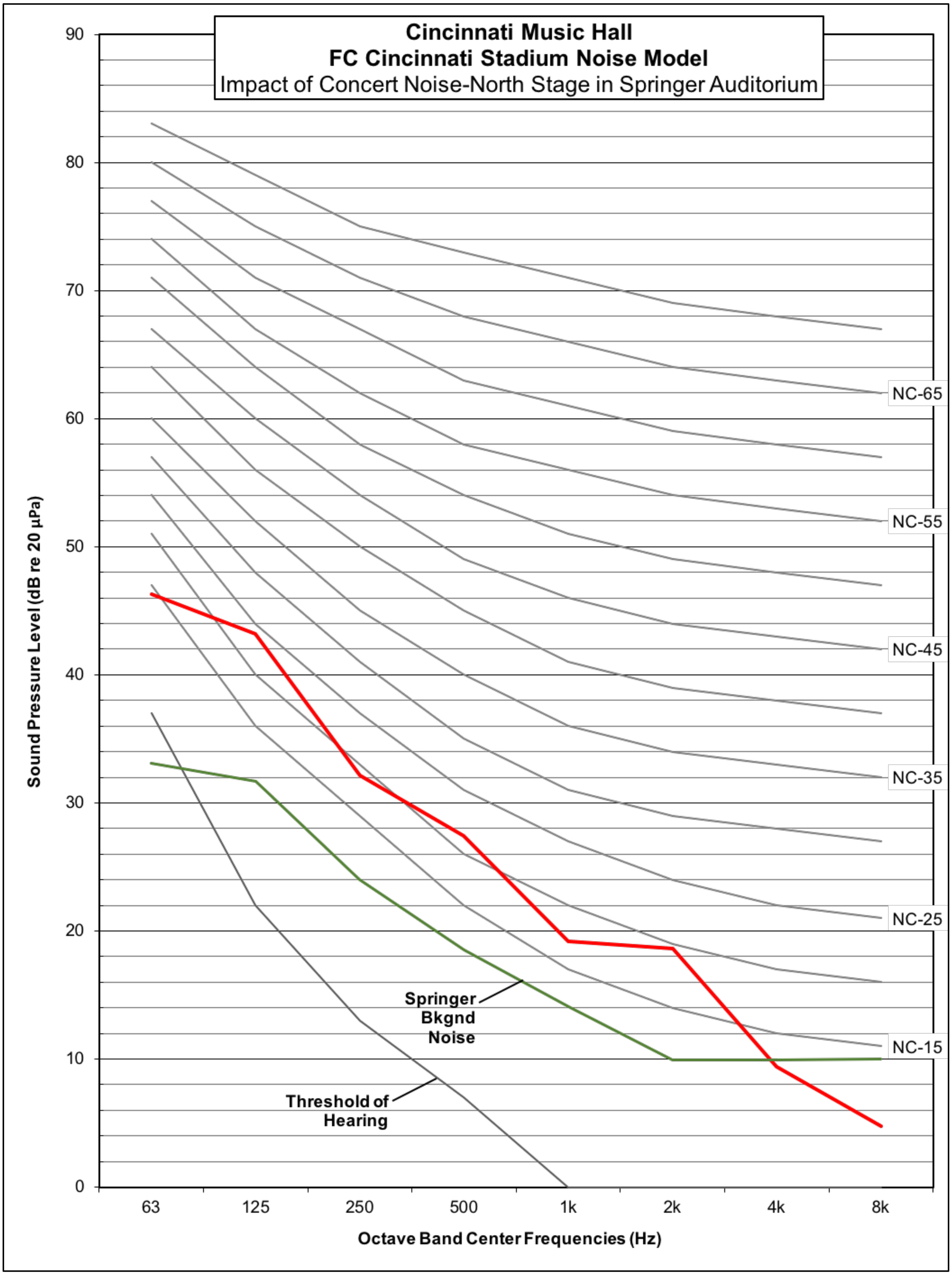

**Graph #2:** Sound source spectrum for amplified contemporary music concert



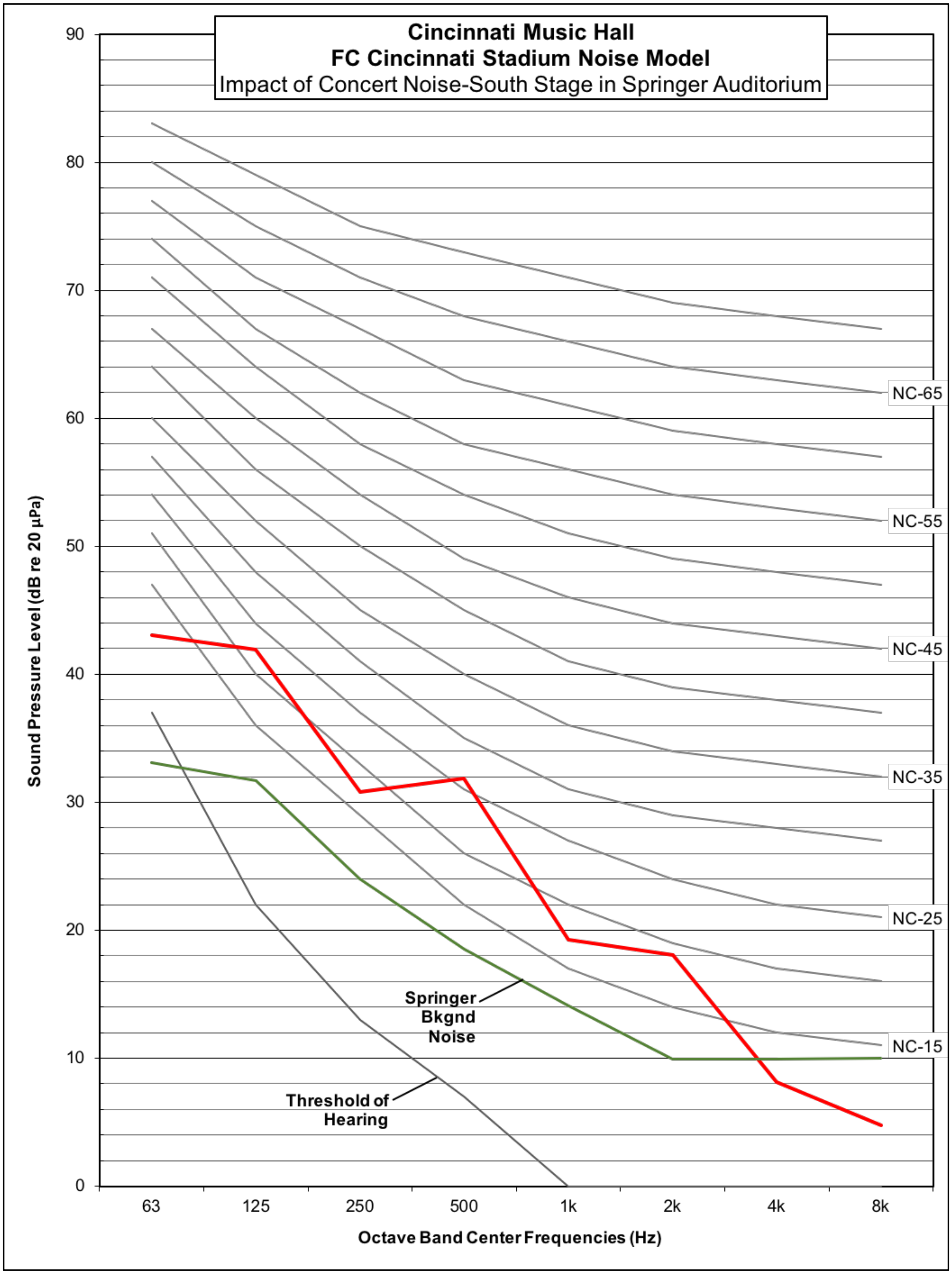
**Graph #3:** Scenario 1 – Crowd Noise in Springer Auditorium



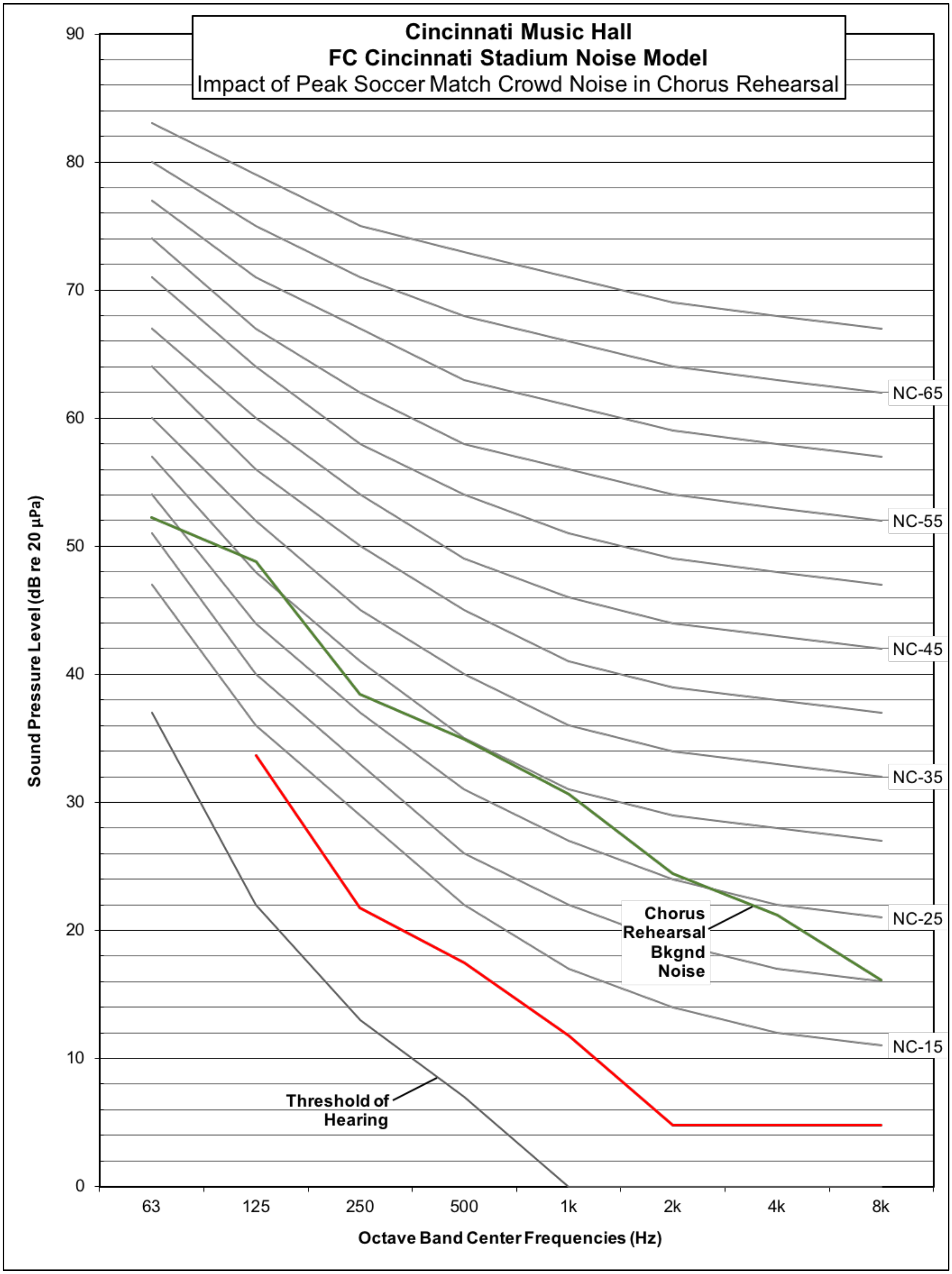
**Graph #4:** Scenario 2 – Concert Noise from North Stage in Springer Auditorium



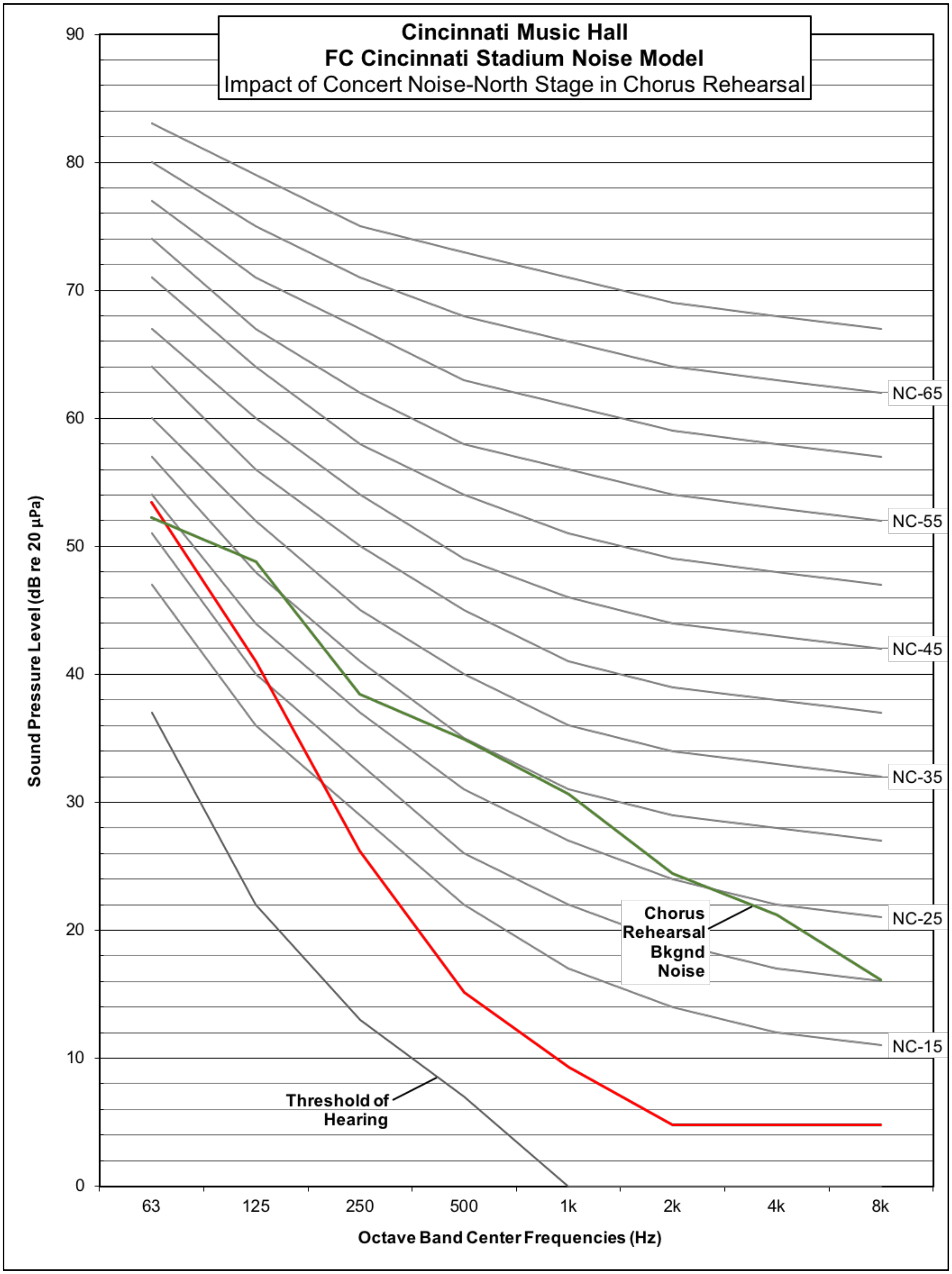
**Graph #5:** Scenario 3 – Concert Noise from South Stage in Springer Auditorium



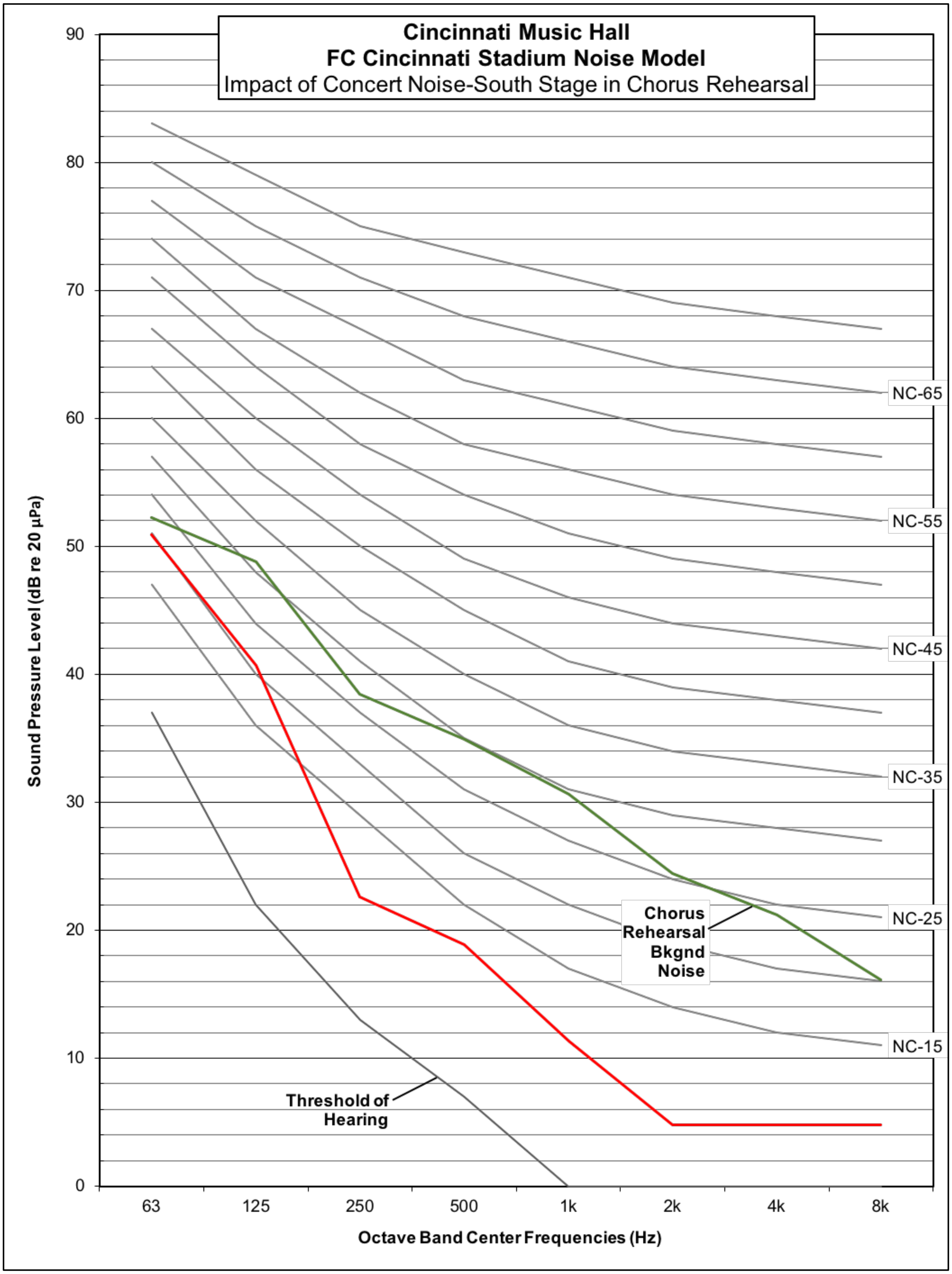
**Graph #6:** Scenario 1 – Crowd Noise in May Festival Chorus Rehearsal Room



**Graph #7:** Scenario 2 – Concert Noise from North Stage in May Festival Chorus Rehearsal Room



**Graph #8:** Scenario 3 – Concert Noise from South Stage in May Festival Chorus Rehearsal Room



**Graph #9:** Scenario 1 – Crowd Noise in the Ballroom

PENDING

**Graph #10:** Scenario 2 – Concert Noise from North Stage in the Ballroom

PENDING

**Graph #11:** Scenario 3 – Concert Noise from South Stage in the Ballroom

PENDING

**Graphs #12, 13, 14 & 15:** Section cut maps through stadium and Music Hall